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Spontaneous alternation as a function of iti and maze position

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ABSTRACT

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Twenty food deprived hooded rats received nine trials per day for a total of fourteen days on an elevated T-maze in a test for spontaneous alternation. Both goal boxes of the T-maze always contained a reward of one dextrose pellet. The experimental design was a 2 x 2 factorial with intertrial interval (ITI) and position of the maze in the experimental room as factors. The experimental room had an extensive extramaze environment and the position of the maze in that room was either unchanged throughout the entire experiment or else the maze was rotated 180 deg. between every trial. The other ITI value was approximately 20-25 sec. It was hypothesized that since spontaneous alternation required memory of the previous trial, both the 20 min. ITI and rotation of the maze should act to reduce alternation. It was found that alternation within each day decreased from the first to the last trial of the day. An interference model was suggested as an explanation for this decrease. Over the fourteen days of the experiment the mean alternation percentages varied from 72.8% for the group with short ITI and constant maze position to 52.7% for the group with 20 min. ITI and constant maze position. The group with short ITI and rotated maze position alternated at 61.6%. It was predicted that the group with 20 min. ITI and rotated maze position would alternate at the lowest rate for all groups; instead this group alternated at

70.7%. Since this result seemed implausible in view of the experimental literature on spontaneous alternation, it was suggested that a replication with more Ss would be desirable.

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SPONTANEOUS ALTERNATION AS A FUNCTION OF ITI AND MAZE POSITION

by

Roy Dennis Cavalcant

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INTRODUCTION

Spontaneous alternation is the tendency for rats to alternate their relative direction of movement on consecutive trials in a T-maze. For example an animal can alternate by turning left at the choice point on one trial and then turning right on the next trial.

Early investigators of spontaneous alternation emphasized its functional significance for rats learning complex mazes. However, the approach taken by most researches was nontheoretical. For instance, Wingfield and Dennis (1934) found that rats alternated in their choice of 2 pathways both leading to the same reward. Weitz and Wakeman (1934) tested the hypothesis that rats alternated to avoid the punishing effects of removal from the goal box while consuming a reward. But the punishment explanation was not supported. Dennis (1935) stressed the importance of using single maze units for the study of alternation behavior which has since become the rule. However, in 1939 he made a significant discovery about alternation behavior in noting that alternation in a hollow-square maze of 2 or more units was specific to each choice point of the maze. According to Dennis (1939) it therefore followed that the rat "without training ... may respond to a choice situation in part on the basis of preceding activity (i.e. prior trial in the maze)" which implies considerable memory for the rat.

Many different theoretical explanations have been proposed for spontaneous alternation, although none have been entirely successful. Using the Hullian concept of "reactive inhibition" (I_r) Zeaman and

House (1951) developed a formal theory for spontaneous alternation which included a number of testable hypotheses. They presumed that with each right or left turn in a T-maze a certain amount of "fatigue" resulted from making the response. Then, if the response probabilities for the two turns were nearly equal, the opposite response would be made on the following trial. They postulated that the inhibited response would spontaneously recover during the rest period. This recovery would produce a non-habituating oscillation in response production (spontaneous alternation). They also predicted that alternation should decrease from trial to trial within each experimental session. This decrease in alternation was postulated since there should be a progressive decrease in the differences between opposing response tendencies that does not dissipate within each experimental session but does so between days. Although some experimenters have not found it (Richter and Kay, 1971), this decrease in alternation has been found by others (e.g., Heathers, 1940).

Rothkopf and Zeaman (1952) found that alternation increased with increased numbers of forced choices to one goal alley, as was predicted by the I_r model. Zeaman and House (1951) found that alternation decreased with delay after a series of forced choices, also as predicted by the I_r model. However, the I_r model falsely predicted that alternation should increase with the amount of "effort" required in making a response. For example, Walker et al. (1955b) found that inclining the arms of a T-maze to 45 deg. decreased alternation instead of increasing it.

It was then suggested by Glanzer (1953) that only a stimulus-type theory could explain spontaneous alternation. He postulated that alternation was due to an accumulation of a boredom-like inhibitory effect which, analygous to I_r, temporarily increased the probability of responding to an alternative. It was shown that, when rats were started from opposite stems in a cross-maze, they repeated responses (e.g. right turn followed by right turn) and therefore, as Glanzer claimed, alternated stimuli and not responses. Furthermore, Glanzer (1953) found that delay in the alternative last chosen increased spontaneous alternation whereas delay out of the maze served to decrease it.

Glanzer called his model a "stimulus satiation" ($_sI$) model. Stimulus-satiation has failed to be an adequate construct. Walker et al. (1955a) prior to a trial in the T-maze, placed rats in the black or white goal boxes of the maze or in other boxes outside of the maze. Neither exposure condition produced a tendency to alternate. Bernhardson (1967) tested the stimulus satiation model by presenting forced choices with the unforced arm blocked by either a clear or opague door. No difference in alternation rates was found. Similarly O'Connell (1971) found that alternation did not differ when rats were given free choices in a maze with clear or opague swinging doors on each goal arm. However Sutherland (1957) found that prefeeding in a goal box before each trial resulted in avoidance of that goal box.

Thompson (1960) attempted to integrate Glanzer's stimulus satiation model with the I_r model by creating a two-factor theory of spontaneous alternation. In his theory inhibition is produced by both I_r

and $_sI$ added together. However, he postulated that $_sI$ developed when an organism makes a response or is exposed to stimuli in the absence of reward whereas I_r developed with or without reward present. Thompson (1960) supported his theory with his finding that animals will alternate less with reward than without it. However, Walker (1956) has found no statistically significant difference in alternation rates when rewarded groups were compared with nonrewarded groups.

An additional though unsupported interpretation for spontaneous alternation was suggested by Estes and Schoeffler (1955). These investigators suggested that a transfer of learning paradigm might prove to be a more parsimonious explanation for alternation than either the I_r or $_sI$ models. They theorized that if animals expected not to receive reward in a place recently visited, they would avoid that place. In the alternation situation this learned reward expectancy principle would result in alternation. Smith (1962), in a direct test of the transfer of learning hypothesis, failed to find support for it.

Explanations for spontaneous alternation are not limited to the class of psychological process models presented above. Another class of models has interpreted alternation behavior as due to biological drives for curiosity and for exploration. Montgomery (1952) suggested that alternation in a cross-maze was a special case of exploratory behavior since goalboxes and not responses were alternated. Dember and Fowler (1958) suggested that alternation could be best understood as an approach response to stimulus novelty. This view of stimulus variation was used in explaining how alternation tendencies dissipated

during the learning of a position habit. It was proposed that reinforcement in learning a position habit operated through two competing kinds of stimulus novelty: that of the unchosen goal arm and that of the stimulation which accompanies consumption of reward (Fowler, Blond, and Dember, 1959). The reinforcing properties of the unentered goal box quickly dissipated and therefore only the response leading to reward was thereafter reinforced.

Any review of the spontaneous alternation literature must stress in addition to theoretical explanations the simple fact, recognized early by Dennis (1939), that alternation requires memory of at least the previous trial in the maze. There is much evidence to support the importance of memory and in general, sensory processing capacity for the rat in the alternation task. Lester (1967) found that the quicker an animal learned a position habit, the higher was his alternation rate as determined by a prelearning test. These results are paradoxical. If alternation were a competing tendency as suggested above, it should result in slower learning of response repetition.

Physiological manipulations have been used to alter memory and sensory processing capacities, followed by post-operative measurement of the alternation rate. Roberts et al. (1962) found that on 2 trials in a T-maze, rats with hippocampal lesions alternated at 59% whereas neocortical operatees alternated at 87%. In a locomotor exploration test, control Ss showed a reduction in activity with time whereas the group with the hippocampal lesions failed to reduce its activity, it was concluded that the reduction in alternation could not be due to

a reduction in exploratory drive. These investigators therefore proposed that:

> At least two processes are involved in the control of exploration during familiarization (memory and/or inhibitory processes). First, a memory of the stimulus must be fixated and retained, and second, the memory must act through some mechanism to reduce the tendency to approach the recently experienced stimulus. A defect in either of these processes could produce the loss of alternation and slower habituation (in the locomotor exploration test) obtained in the present experiments.[1]

Furthermore Douglas and Raphelson (1966) found that bilateral septal lesions reduced alternation to chance. They concluded that disruption of inhibitory processes was the cause of the reduction since lesion of the septal area is known to increase response perseveration. However, Kirkby (1969) has suggested that the deficits in alternation rate may rather be due to decreased efficiency of the organism's acquisition and integration of sensory information.

It has been shown that when learning ability is impaired spontaneous alternation is found at low rates. Using animals with hippocampal lesions Lash (1964) found that the more an animal alternated, the more readily he learned a subsequent successive discrimination. Kirkby and Kirkby (1968) found that rats reared in an enriched environment alternated more than those reared in individual cages. Furthermore Kirkby (1967) found that alternation increases with maturation as does the ability to learn.

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[1]W. Roberts, W. Dember, and M. Brodwick, Alternation and exploration in rats with hippocampal lesions. Journal of Comparative and Physiological Psychology, 1962, 55, p. 700.

If memory is important for spontaneous alternation then it follows that the intertrial interval (ITI) is an important variable in the study of spontaneous alternation. Experimental findings on the effect of ITIs of different durations are very disparate. Heathers (1940) using an elevated T-maze and rewarded trials found that alternation progressively decreased from a maximum of 85.6% for the shortest ITI (15 sec.) to 65.6% for a 120 sec. ITI. Furthermore alternation with an ITI of 15 min. was near chance of 50%. Riley and Shapiro (1952) found above chance alternation with a 25 sec. ITI but not with a 5 min. ITI. However, Walker (1956) has reported significant alternation occurring with an ITI as long as 90 min. His animals were retained in the goal box for 60 sec. after each trial. Since such delay in the goal box has been shown to increase alternation (Glanzer, 1953), it is possible that delay can also attenuate the effect of ITI. It is clear that more research is needed to resolve the differences between these studies.

Recently work in spontaneous alternation has become less theoretical. There has been considerable interest in discovering which stimulus cues an animal utilizes when alternating. Much of the new work concerns Douglas's (1966) proposal that alternation is controlled by two cues (at least in the case of two, nonrewarded trials per day). These cues are: (1) a tendency to avoid the odor trail in the goal arm last entered (a response requiring no memory of the previous trial), and (2) a more powerful tendency to use vestibular information from the inner ear and thereby alternate spatial direction. This is a departure

from earlier notions about spontaneous alternation in that Douglas did not find evidence for the use of visual cues whereas Walker et al. (1955), using a cross-maze with response repetition (resulting in alternation of stimuli) defined as alternation, found evidence for alternation to both "place" in the room and to intramaze visual stimuli. In Douglas's experiment it is not clear if the rats could attend to extramaze visual stimuli since the stimuli were placed on the ceiling of the maze. However, alternation to visual stimuli appears unlikely since Klein and Brown (1969) have found that blinded rats alternate as well as do controls.

Douglas's evidence for alternation to turn-direction was that rats alternated at 81.3% on two unrewarded trials in identical mazes, at 61.5% with parallel mazes pointed in opposite directions, and at chance (below 50%) with mazes pointed perpendicular to each other. Giving each animal rapid turns in a horizontal plane at the beginning of each trial resulted in close to chance alternation. Turns in a vertical plane or rolling the animals did not reduce the alternation rate. Douglas (1966) also found that rats with an inner ear disease lacked spontaneous alternation after the odor trail had been removed.

Douglas's findings were confirmed by Sherrick and Dember (1966). They discovered that if rats run trial one in a straight alley and are then allowed to run a T-maze on trial two, they will choose on trial two in the T-maze the goal arm that is in the opposite direction of their trial one movement. Rosen and Stein (1969) confirmed that alternation to direction was a more powerful determining factor than was

avoidance of odor trail. Richman and Tessnear (1969) found that they could predict turn-direction at the choice-point of a T-maze by observing the direction in which the animal completed a full turn in the startbox (clockwise or counter-clockwise). If an animal went clockwise in the start box he would alternate this direction by choosing left at the choice-point and vice versa.

The evidence for alternation to odor trail is likewise compelling. Douglas (1966) found alternation at 65.6% to odor cues alone. Klein and Brown (1969) found that anosmic animals alternated at chance when the mazes were perpendicular to each other. However, there is evidence which suggests that the odor trail does not result in avoidance per se. Still and Macmillan (1969) found significant alternation in conditions in which the odor trail was reversed as a cue (i.e. switched to the unentered goal arm). Since during both trials the odor trail was present in the start stem this was the part of the odor trail to which the rats were alternating. It was then postulated that alternation required the rat to make two decisions on every trial. First, it had to decide whether the maze had been entered before (i.e. odor in start stem or not). The second decision was made if and only if the first decision was in the affirmative; this decision required the rat to remember which goal arm it had entered on the preceding trial. Still and Macmillan do not explain how decision one is made when alternation occurs to the direction of movement with odor trails totally absent.

The present experiment was an attempt to further test two hypotheses about spontaneous alternation. First, from the literature it

was not clear how ITI would be related to alternation when several free choice trials were given each day. It was hypothesized that animals had an innate tendency to alternate which depended on memory of the previous trial. Therefore, a short ITI should produce more alternation than a long one since more forgetting should occur during the long ITI. In addition it was predicted that alternation should decrease from trial to trial during each day and then fully recover on the following day. This prediction was based on the assumption that memory of preceding trials should interfere with memory of the immediately preceding trial to reduce spontaneous alternation.

Second, it was hypothesized that rotating the maze 180 deg. between trials should slightly reduce spontaneous alternation. Douglas (1966) had found that antiparallel maze positions (two trials only) decreased alternation. This reduction in alternation could be due to some disorientation of the animal's sense of direction.

METHOD

Subjects. Twenty-three male Long-Evans rats supplied by Huntington Farms served as Ss. They were 90-120 days old and weighed approximately 220 grams upon arrival. Ss were housed individually in their home cages. They were gentled by individual handling and were then put on a 23 h. deprivation cycle for the two weeks preceding the first experimental session. Water was available at all times in the home cages and animals received one hour ad lib feeding each day.

Apparatus. An elevated T-maze was constructed without a start box and with a goal box at the end of each alley. All sections were 2 in. wide and were constructed of clear white pine. The start stem consisted of a 2 ft. section attached to an 8 ft. section such that it divided it into two 4 ft. goal alleys. The goal boxes were identical; both were 4 in. wide, 10 in. long, and 6 in. high. Alleys and goal boxes were painted a flat gray. Goal boxes were provided with white plexiglass guillotine doors which could be lowered by strings attached to the starting stem. The entire maze was mounted on three legs made from 2 x 4's, each 3 ft. long and provided with casters to make rotation of the maze easy.

The maze was located in the center of a large L-shaped room providing an extensive extramaze environment. Lighting was provided by incandescent lights recessed in the ceiling.

At the beginning of each experimental session the rack holding the home cages was moved from the animal room to a small room adjoining

the room containing the T-maze.

Procedure. There were 5 consecutive days of pretraining. During the first 2 days animals in groups of 4 or 5 were given 15 min. free exploration of the maze. On the remaining 3 days each animal was placed alone on the maze for 5 min. Records were kept of their initial choice preferences. At this time three animals were discarded because of their refusal to run the maze. While being habituated to the maze the animals learned to eat 45 mg. Noyes dextrose pellets. These pellets were placed in glass dishes and were eaten in the home cage prior to the daily feeding.

The two treatment factors (ITI and maze position) were arranged in a factorial design. Half the Ss had either a 20-25 sec. (S) or 20 min. (L) ITI and half the Ss for each ITI received either a constant (C) or rotated (R) maze position. There were then four experimental groups (group SC, group SR, group LC, and group LR). Ss were assigned at random to each of the four experimental groups.

The experiment proper was run on the next 14 days. Each group received 9 trials per day allowing for a maximum of 8 possible alternations. Every response (i.e. right or left turn) was always rewarded with a dextrose pellet placed in a glass dish. The animal remained in the goal box for a minimum of 15 sec. or until he had consumed the reward and was then removed by the experimenter. Between trials short ITI animals were placed in a retaining cage of the same type as the home cage and a board was used to cover the top. Long ITI animals were returned to their home cages between trials.

Retracing of the goal arms was possible but only occurred twice in the experiment. Any defecation or urination which occurred was quickly wiped away.

Each experimental session began at 1 PM and usually was over by 5 PM. Animals in the short ITI condition were run at different times during the session so that the groups could be equated for deprivation level. Animals in the long ITI condition were run as groups. After the first day the running order for the animals in all four groups was held constant throughout the remainder of the experiment.

RESULTS

The mean alternation rates for the different experimental groups were calculated as percent alternation for the 14 days of the experiment. Group SC alternated at 72.8% with one animal discarded[2] (63.2% with all 5 animals); group LR at 70.7%, group SR at 61.6% and group LC at 52.7%. Group SC alternated the most as was hypothesized. However, group LR, instead of alternating the least, alternated almost as much as group SC. Examination of the individual subjects' alternation rates revealed that 2 animals in group LR alternated at very high rates (92.8% and 84.8%).

All scores were calculated over trial blocks of two days to simplify graphical representation. Figure 1 shows how alternation varied over trial blocks. Note that all groups except group LC appeared to spontaneously alternate above the chance level. Furthermore alternation did not appear to reach a peak until several days after the first day's trials, whereafter it declined moderately. The ranges for the group means analyzed in blocks of two days were (60.9-87.5%) for group SC, (62.5-80.0%) for group LR, (55.0-67.5%) for group SR, and (46.2-58.8%) for group LC.

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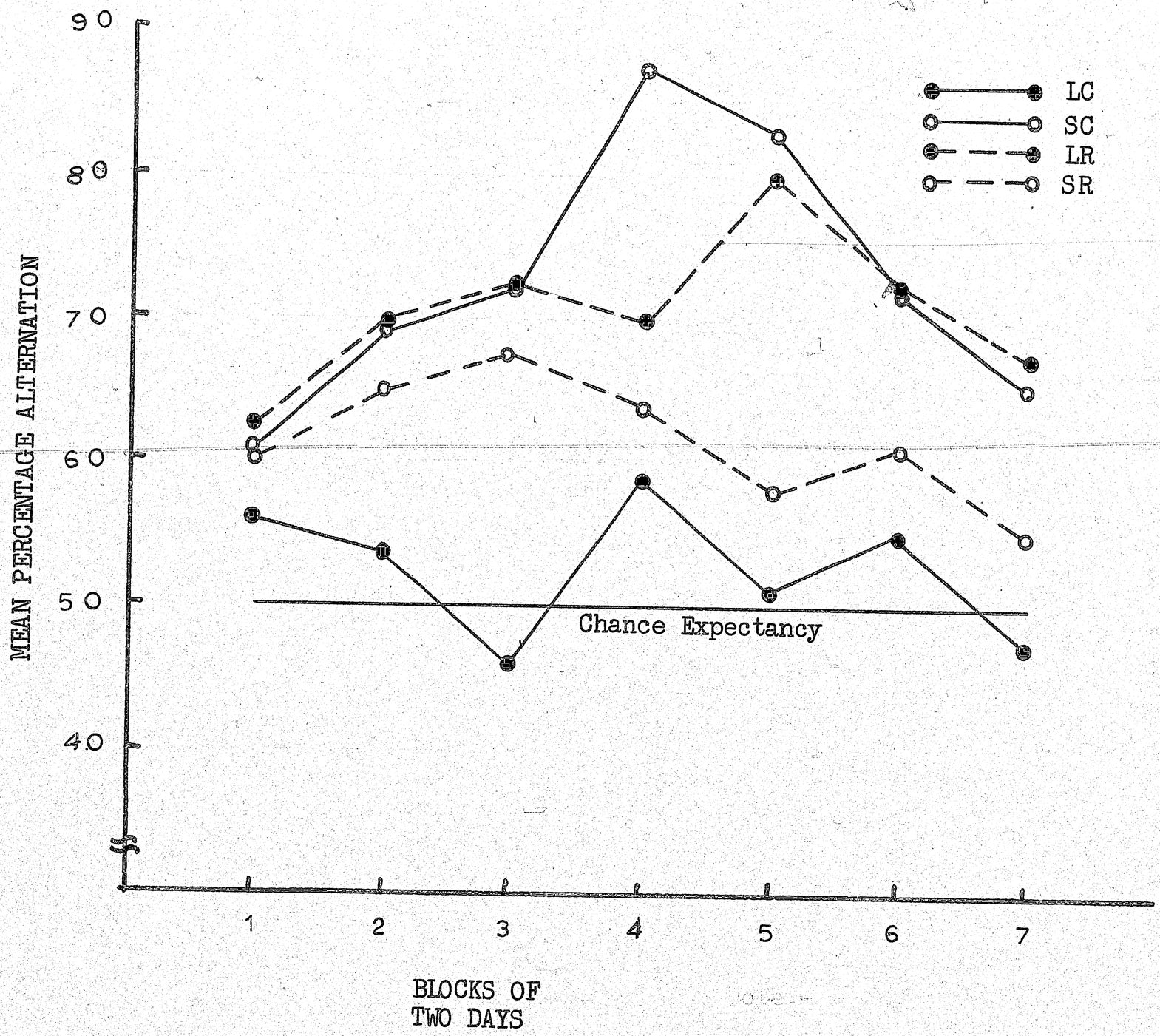
[2]The animal was discarded from further analysis of the data due to hyperemotionality (defecation and urination) and due to extremely long choice latencies (over 10 minutes). Furthermore the animal was sometimes coerced by gentle prodding to make a choice. Still (1966) presents evidence that the use of coercion results in response repetition. This appeared to be the case with the discarded animal.

Figure 1. Mean percentage alternation for the four experimental groups over blocks of two days.


90
80
70
60
50
40
MEAN PERCENTAGE ALTERNATION
LC
SC
LR
SR
Chance Expectancy
1
2
3
4
5
6
7
BLOCKS OF
TWO DAYS

For the sake of doing an analysis of variance, an arcsin transformation was applied, as recommended by Owen (1962, p. 293), to the alternation proportions. The transformation was for individual S's two day block proportions of alternation. Figure 2 shows the results of the transformation over two day blocks.

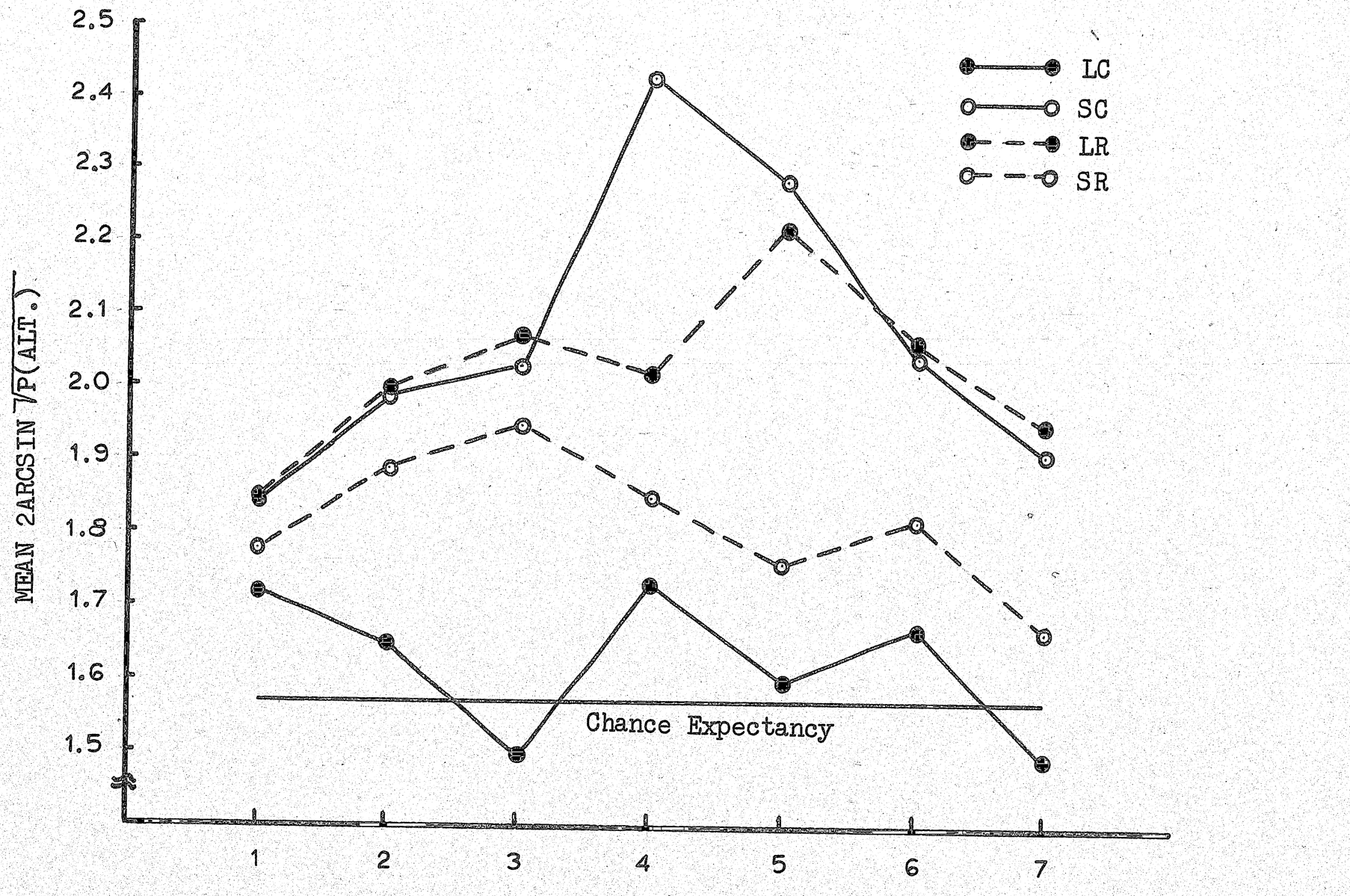
An analysis of variance was conducted on the transformed scores with two day blocks as a within-subject factor. The method of unweighted means (Winer, 1962, p. 293) was used since the groups had unequal cell frequencies. Table 1 shows that the interaction effect for ITI and maze position just reached significance for $p < .05$. Figure 3 shows the interaction effect with the untransformed scores. None of the main effects were statistically significant.

To discover how alternation varied from trial to trial alternation rates were averaged over the 7 two day blocks for each of the 8 pairs of daily trials. Figure 4 reveals an overall decrease in percent alternation from the first to the last trial of the day. This decrease appeared for all groups except group LC which appeared to oscillate around the level of chance. It therefore appears that this group was not alternating above chance.

Table 2 shows that a significant within-days trial effect was found ($p < .05$) with an analysis of variance of the transformed scores. The ITI and maze position interaction just missed significance ($F = 4.51$).

Figure 5 shows alternation decreasing over trials for all groups combined. It appeared that the shape of the curve might be

Figure 2. Mean of transformed scores for the four experimental groups over blocks of two days.



Note.- When P (ALT.) = 0, ϕ_o = 2 arcsin$\sqrt{\frac{1}{4n}}$
When P (ALT.) = 1, $\phi_1 = \pi - \phi_o$

TABLE 1

Analysis of Variance with Blocks of Two Days

as a Within-Subject Factor

SOURCE	SS	DF	MSQ	F
ITI (A)	.5096	1	.5096	< 1
Maze position (B)	.1633	1	.1633	< 1
AB	3.5966	1	3.5966	4.9499*
$Error_b$	10.8990	15	.7266	---
Blocks of 2 days (C)	.8611	6	.1435	1.0574
AC	.2056	6	.03426	< 1
BC	.3938	6	.06563	< 1
ABC	.6508	6	.1084	<1
$Error_w$	12.2210	90	.1357	----

* ($p < .05$)

Figure 3. A x B interaction demonstrating the greater mean alternation rate in the rotated position than in the constant maze position when the ITI was 20 min.

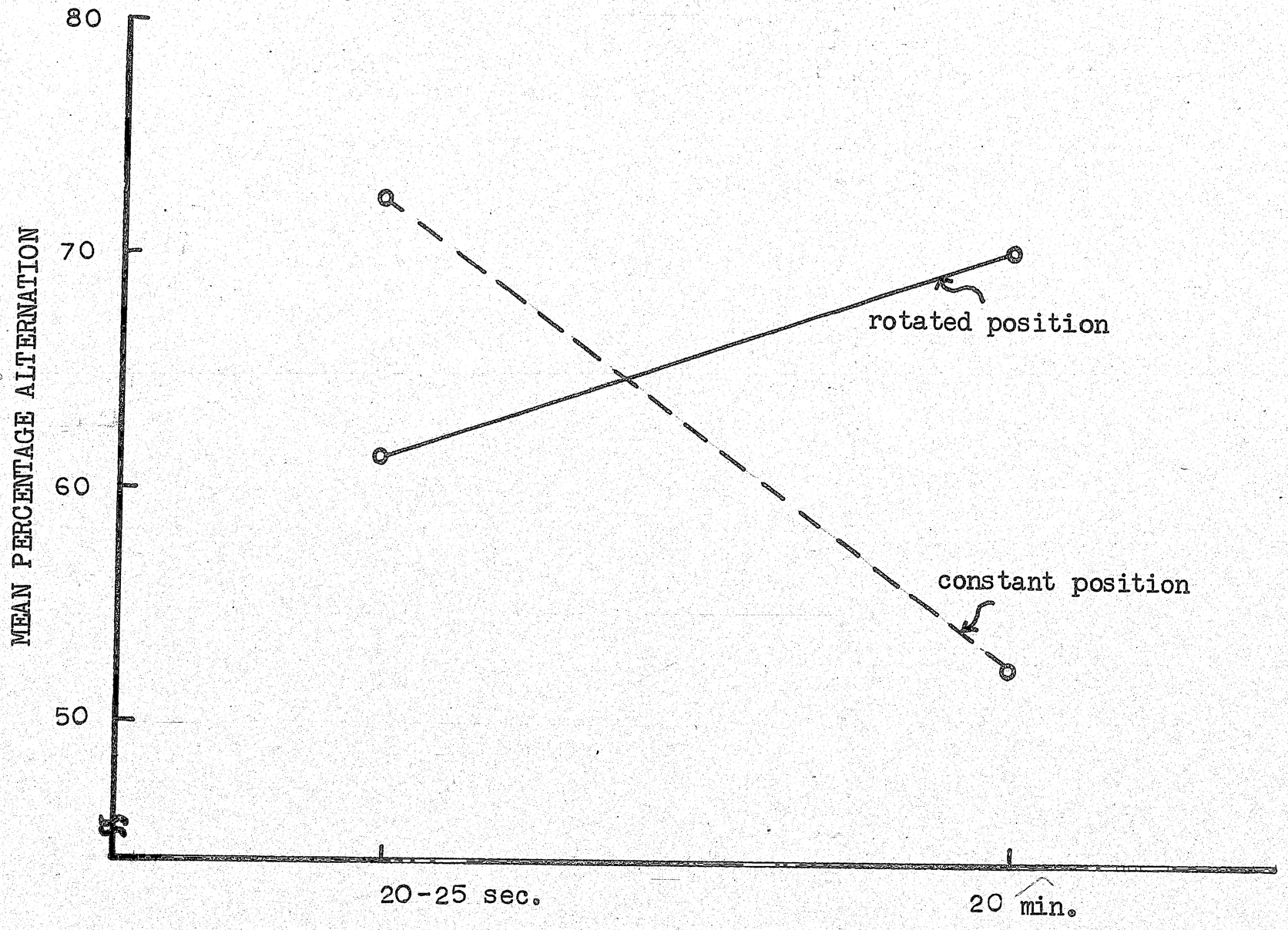

80
70
60
50
MEAN PERCENTAGE ALTERNATION
rotated position
constant position
20-25 sec.
20 min.
ITI

Figure 4. Mean percent alternation over each day's trials for the four experimental groups.

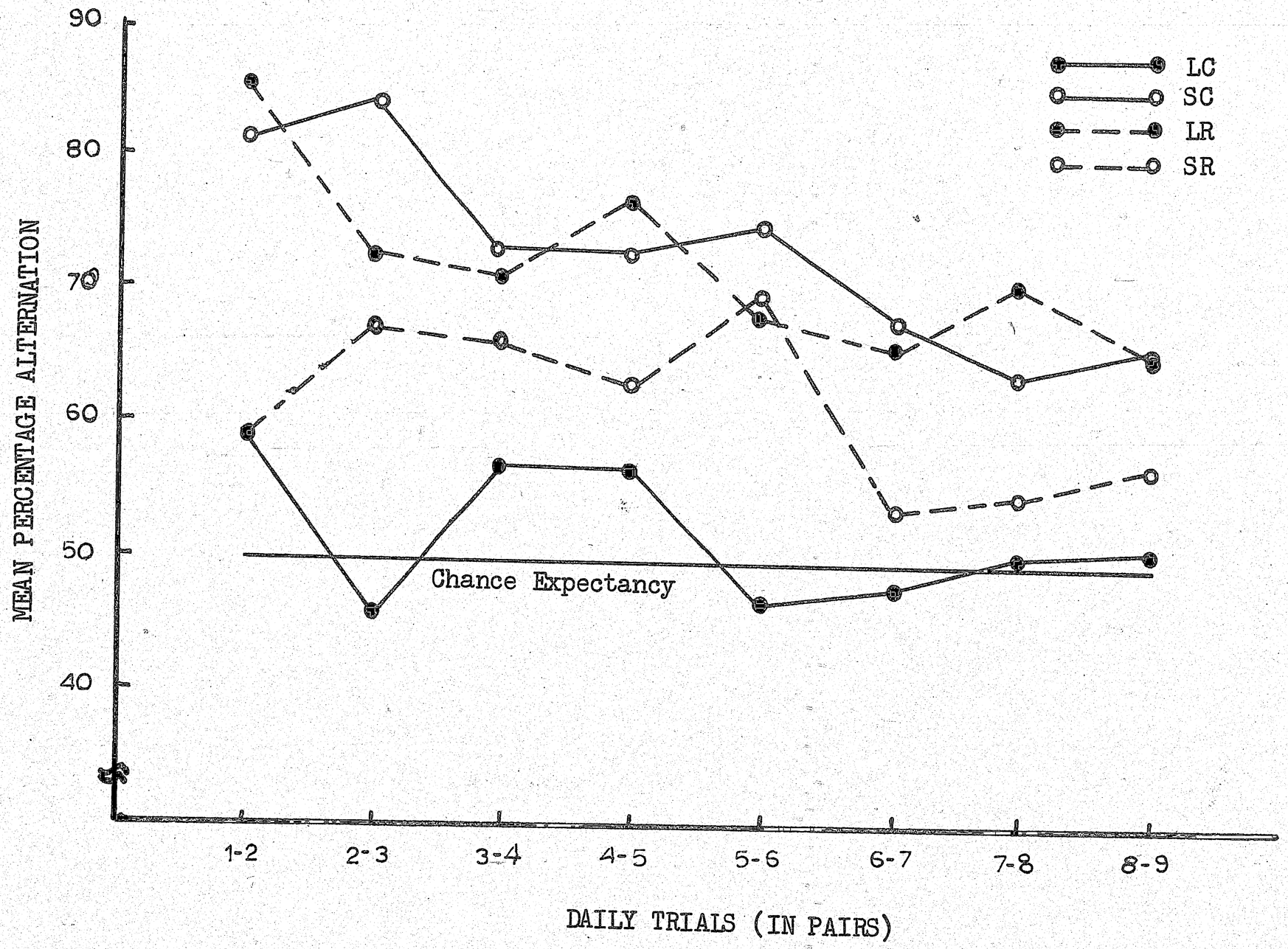

90
80
70
60
50
40
MEAN PERCENTAGE ALTERNATION
LC
SC
LR
SR
Chance Expectancy
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
DAILY TRIALS (IN PAIRS)

TABLE 2

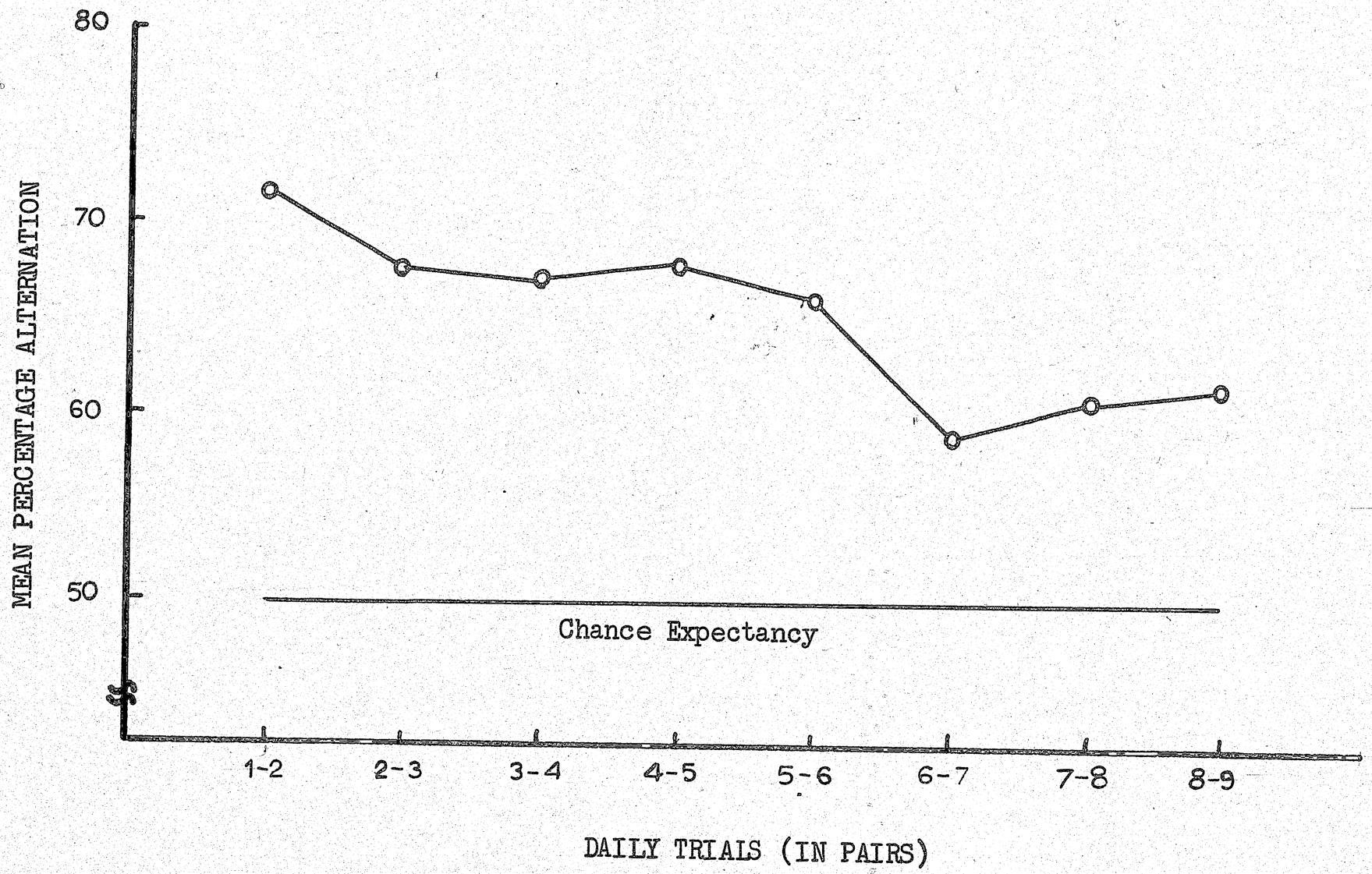
Analysis of Variance of the Within-Day Trial Effect

SOURCE	SS	DF	MSQ	F
ITI (A)	.5195	1	.5195	<1
Maze position (B)	.3811	1	.3811	<1
AB	3.6479	1	3.6479	4.514 N.S.
$Error_b$	12.1244	15	.8082	----
Daily trials (D)	1.0489	7	.1498	2.335*
linear	.7915	1	.7915	12.252**
non-linear	.2574	6	.04283	.662
AD	.6945	7	.0992	1.546
BD	.08423	7	.01203	<1
ABD	.5543	7	.07919	1.234
$Error_w$	6.7369	105	.06416	----

* ($p < .05$)

** ($p < .001$)

Figure 5. Mean percent alternation over each day's trials for all groups combined.


MEAN PERCENTAGE ALTERNATION
80
70
60
50
Chance Expectancy
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
DAILY TRIALS (IN PAIRS)

cubic and therefore an analysis of variance test for trends was conducted. There was a highly significant linear trend with $p < .001$ ($F_{1,105} = 12.252$) and the non-linear trend was nonsignificant ($F_{6,105} = .662$).

It has been pointed out by Dember and Fowler (1958) that the 50% level for chance is a conservative estimate since any position preferences should reduce the proportion of alternation to be expected by chance alone. The number of right and left turns were therefore examined for each subject. Table 3 shows every subject's first turn on each of the three days of nonrewarded maze exploration. Also shown in table 3 are each subject's total number of right and left turns during the 14 days of training and the number of right and left turns for the first trial of the day only. Inspection of the pretraining turn preferences and of those exhibited during training does not appear to reveal any consistent relationship existing between the two. Therefore it appears unlikely that the animals were responding to the alternation situation on the basis of position preference although this may be true for a few individual Ss.

TABLE 3

Each Subject's Right and Left Turns for the Free Exploration Period and for the Training Period

	Free Exploration			Training			
	First Turn Made			Total No. Turns		Turn Made on Trial 1	
Ss	Day 1	Day 2	Day 3	No. L	No. R	No. L	No. R
1	*	L	R	38	88	3	11
2	*	R	L	65	61	7	7
3	L	L	L	85	41	10	4
4	L	R	L	61	65	5	9
5	*	L	L	79	47	7	7
6	R	L	R	35	91	7	7
7	L	L	L	42	84	6	8
8	R	R	R	71	55	11	3
9	L	L	L	54	72	6	8
10	*	R	L	58	68	8	6
11	R	L	L	96	30	14	0
12	R	L	L	74	52	9	5
13	R	L	L	67	59	8	6
14	R	R	L	36	90	3	11
15	*	L	L	7	119	1	13
16	L	L	R	67	59	9	5
17	R	R	L	60	66	3	11
18	L	R	L	65	61	10	4
19	L	L	R	11	115	2	12

*animal did not run

DISCUSSION

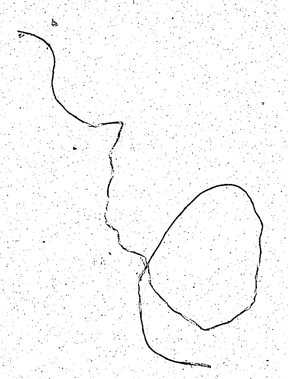
The results were surprising in that the hypothesized main effects of ITI and maze position did not appear in this experiment. If it is assumed that alternation is an innate or spontaneous tendency (the rate of which is dependent on memory for the previous trial) then long ITI and rotated maze position should reduce alternation by impairing memory. A long ITI should produce more forgetting than a short one. However what is debatable is the duration of the ITI necessary to produce any decrease in rate, cf. Walker (1956) with Riley and Shapiro (1952). The present experiment again suggests that the conditions under which ITI reduces alternation are highly variable and may depend on the overall experimental procedure.

Douglas's (1966) finding that alternation on two trials in anti-parallel mazes reduces alternation is partially confirmed by the finding that group SR alternated less than group SC. It would appear that confusion from starting at different positions (in the rotated condition) was not a very powerful effect since group SR alternated above chance.

It is plausible that the 70.7% alternation for group LR is spuriously high since this group included two Ss with the highest alternation rates for all Ss. Although the AB interaction just made significance at the .05 level, it is the feeling of the experimenter that a replication of the results would be necessary before the AB interaction can be believed. It is suggested that more Ss be used

to increase the power of the statistical tests applied to the alternation scores.

The hypothesis that alternation should decrease over trials was clearly supported for all experimental groups except for the group which alternated at chance. It would be of some interest to investigate whether alternation will become chance with more than 9 trials per day. It is possible that more than 9 trials will not further reduce alternation.



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VITA

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